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(54) **LED DIE AND METHOD OF MANUFACTURING THE SAME**

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(51) **Int. Cl.**

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H01L 33/32	(2010.01)
H01L 33/42	(2010.01)
H01L 33/46	(2010.01)
H01L 33/20	(2010.01)

(52) **U.S. Cl.**

CPC ***H01L 33/0025*** (2013.01); ***H01L 33/0075*** (2013.01); ***H01L 33/06*** (2013.01); ***H01L 33/20*** (2013.01); ***H01L 33/32*** (2013.01); ***H01L 33/42*** (2013.01); ***H01L 33/46*** (2013.01); *H01L 2933/0016* (2013.01); *H01L 2933/0025* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2007/0085095	A1*	4/2007	Ko et al.	257/94
2009/0283789	A1*	11/2009	Kim et al.	257/99
2012/0228580	A1*	9/2012	Wang et al.	257/13
2013/0168718	A1*	7/2013	Shin et al.	257/98

FOREIGN PATENT DOCUMENTS

TW	201310703 A1	3/2013

* cited by examiner

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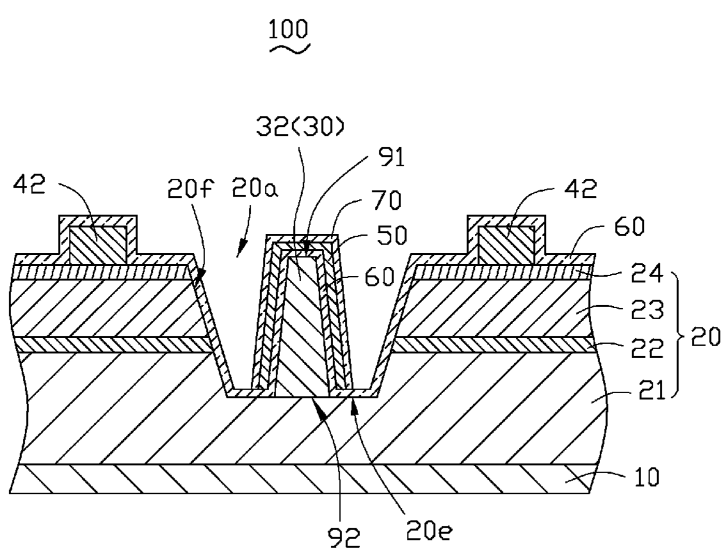
(57) **ABSTRACT**

An LED die includes a substrate, a light emitting structure, electrodes, a first transparent protecting layer, a reflection layer, and a second transparent protecting layer. The light emitting structure includes a first semiconductor layer, an active layer, a second semiconductor layer successively formed on the substrate. A part of first semiconductor layer being exposed. A first electrode is formed the first semiconductor layer. A second electrode is formed on the second semiconductor layer. The first transparent protecting layer, the reflection layer, and the second transparent protecting layer successively formed on the first electrode. The present disclosure also provides a method of manufacturing the LED die.

20 Claims, 3 Drawing Sheets



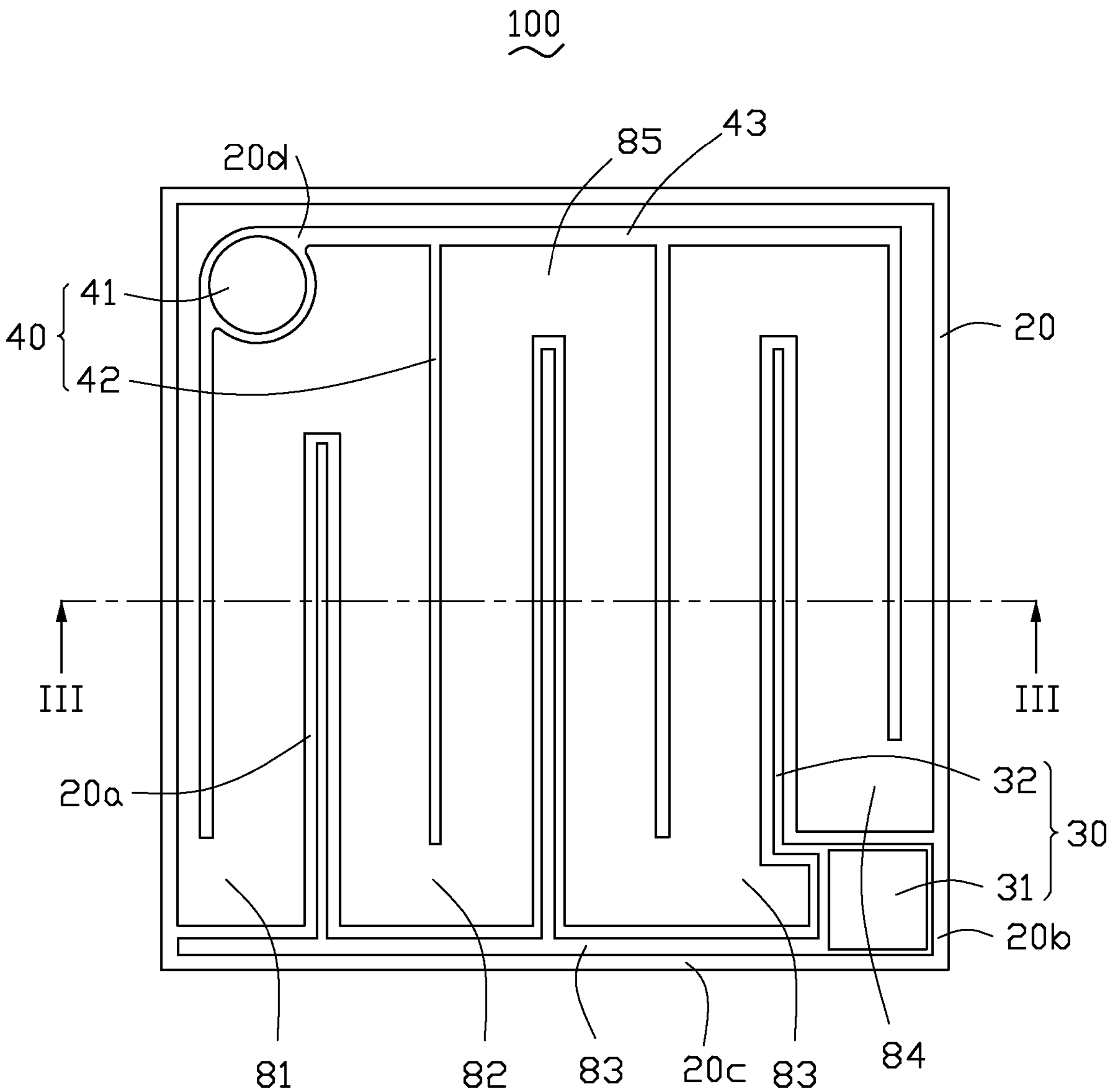


FIG. 1

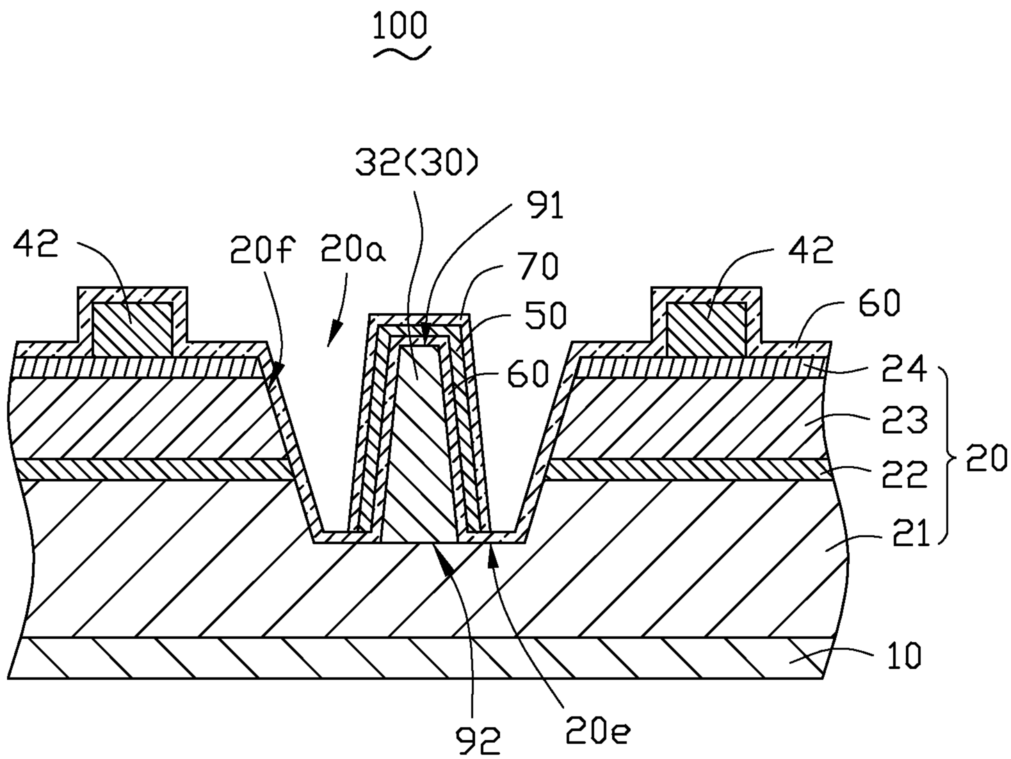


FIG. 2

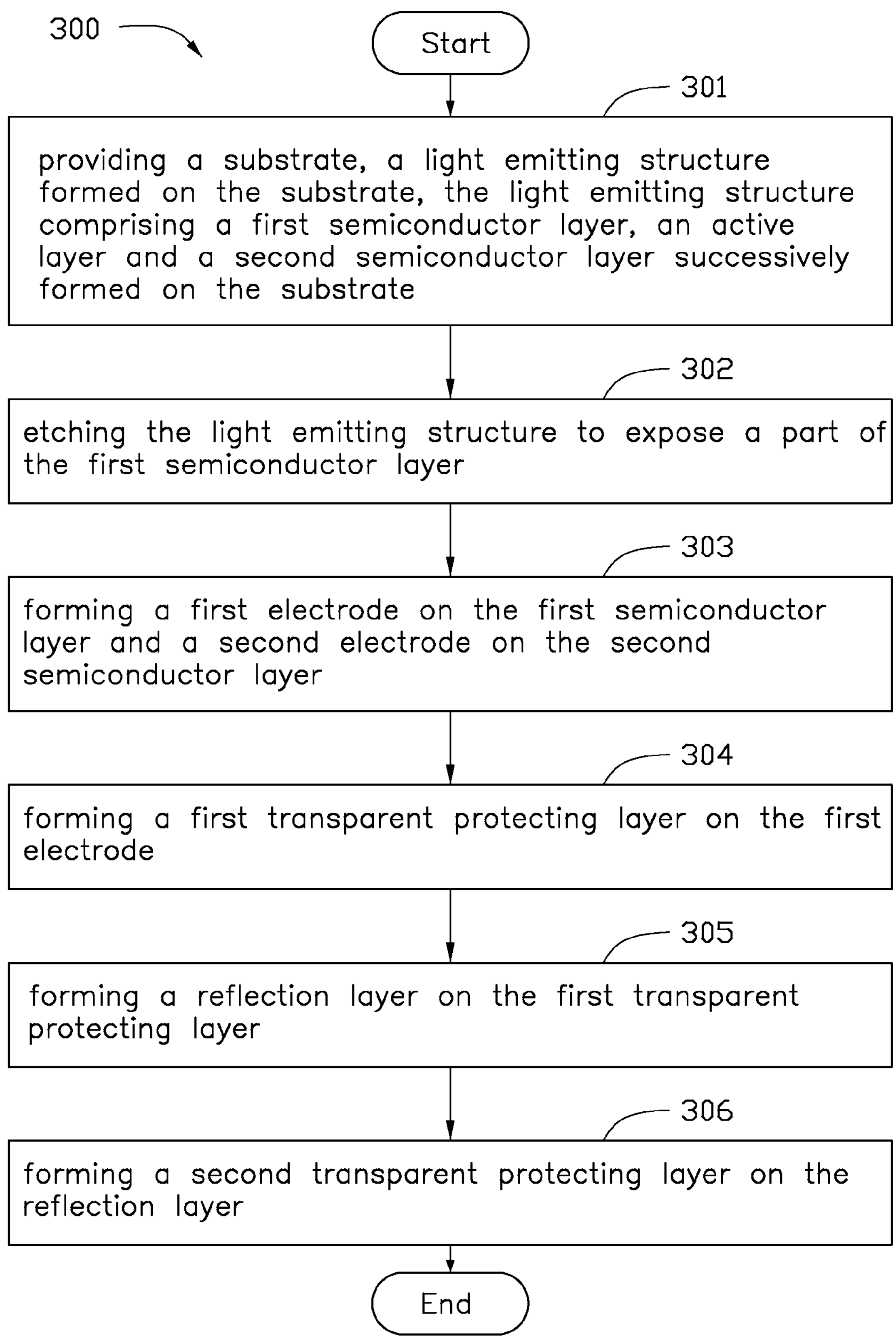

300
Start
301
providing a substrate, a light emitting structure formed on the substrate, the light emitting structure comprising a first semiconductor layer, an active layer and a second semiconductor layer successively formed on the substrate
302
etching the light emitting structure to expose a part of the first semiconductor layer
303
forming a first electrode on the first semiconductor layer and a second electrode on the second semiconductor layer
304
forming a first transparent protecting layer on the first electrode
305
forming a reflection layer on the first transparent protecting layer
306
forming a second transparent protecting layer on the reflection layer
End

FIG. 3

LED DIE AND METHOD OF MANUFACTURING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to Chinese Patent Application No. 201330352683.2 filed on Aug. 14, 2013 in the State Intellectual Property Office Of The P. R. C, the contents of which are incorporated by reference herein.

FIELD

The disclosure relates to an LED (light emitting diode) die and a method of manufacturing the LED die.

BACKGROUND

An LED die typically includes a light emitting structure and electrodes. Electrodes can electrically connect the light emitting structure to a PCB (printed circuit board).

BRIEF DESCRIPTION OF THE DRAWINGS

Implementations of the present technology will now be described, by way of example only, with reference to the attached figures.

FIG. **1** is a top view showing an LED die in accordance with an exemplary embodiment of the present disclosure.

FIG. **2** is a partial-cross section view showing the LED die of FIG. **1**.

FIG. **3** is a flow chart of a method of manufacturing an LED die in accordance with an exemplary embodiment of the present disclosure.

DETAILED DESCRIPTION OF EMBODIMENTS

It will be appreciated that for simplicity and clarity of illustration, numerous specific details are set forth in order to provide a thorough understanding of the embodiments described herein. However, it will be understood by those of ordinary skill in the art that the embodiments described herein can be practiced without these specific details. In other instances, methods, procedures and components have not been described in detail so as not to obscure the related relevant feature being described. Also, the description is not to be considered as limiting the scope of the embodiments described herein. The drawings are not necessarily to scale and the proportions of certain parts have been exaggerated to better illustrate details and features of the present disclosure. The description is not to be considered as limiting the scope of the embodiments described herein.

Several definitions that apply throughout this disclosure will now be presented. The term “comprising” means “including, but not necessarily limited to”; it specifically indicates open-ended inclusion or membership in a so-described combination, group, series and the like. The term “coupled” is defined as connected, whether directly or indirectly through intervening components, and is not necessarily limited to physical connections. The connection can be such that the objects are permanently connected or releasably connected. The term “electronically coupled” can include any coupling that is via a wired or wireless connection. The electronic coupling can be through one or more components or it can include a direct connection between the described components.

Referring to FIGS. **1** and **2**, an LED die **100** includes a substrate **10**, a light emitting structure **20** formed on the substrate **10**, and a first electrode **30** and a second electrode **40** formed on the light emitting structure **20**.

The substrate **10** can be made of sapphire, silicon carbide (SiC), silicon (Si), gallium arsenide (GaAs), lithium metaaluminate ($LiAlO_2$), magnesium oxide (MgO), zinc oxide (ZnO), gallium nitride (GaN), aluminium nitride (AlN) or indium nitride (InN). The substrate **10** can be made of monocrystal.

The light emitting structure **20** comprises a first semiconductor layer **21**, an active layer **22**, and a second semiconductor layer **23**. The first semiconductor layer **21**, the active layer **22**, and the second semiconductor layer **23** are successively formed on the substrate **10**. In at least one embodiment, the first semiconductor layer **21** is an N-type doped semiconductor layer, and the second semiconductor layer **23** is a P-type doped semiconductor layer. The N-type doped semiconductor layer can be made of $Al_xGa_{1-x}N$ ($0 \leq x < 1$), and doped with an N-type impurity. There are no particular limitations for the n-type impurity, and suitable examples include silicon, germanium (Ge), or tin (Sn), etc. The active layer **22** is laminated on the top of the first semiconductor layer **21**, the active layer **22** can be a single quantum well structure, a multiple quantum well structure, or the like. The P-type doped semiconductor layer can be made of $Al_xGa_{1-x}N$ ($0<x<1$), and doped with a P-type impurity, the P-type impurity can be made of magnesium (Mg), zinc (Zn) or beryllium (Be), etc. In an alternative embodiment, the first semiconductor layer **21** and the second semiconductor layer **23** can be a P-type doped semiconductor layer and an N-type doped semiconductor layer, respectively.

The light emitting structure **20** can also include a transparent conducting layer **24**. The transparent conducting layer **24** is formed on the second semiconductor layer **23** by evaporation, sputtering, etc. The transparent conducting layer **24** can be made of indium tin oxide (ITO), indium zinc oxide (IZO), aluminum zinc oxide (AZO), gallium zinc oxide (GZO), gallium indium oxide (GIO), indium gallium zinc oxide (IGZO).

A plurality of grooves **20*a***, a first connecting area **20*c*** and a flat area **20*b*** are formed from the transparent conducting layer **24** to the first semiconductor layer **21** by etching. The first connecting area **20*c*** is formed at peripheral flanges of the light emitting structure **20**. The grooves **20*a*** are connected to the flat area **20*b*** by the first connecting area **20*c***. The grooves **20*a*** are perpendicular to and extend from the first connecting area **20*c***. The first connecting area **20*c*** extends from the flat area **20*b***. A flank **20*f*** of each groove **20*a*** can be an inclined surface. The grooves **20*a*** are parallel to each other.

A part of first semiconductor layer **21** can be exposed. In at least one embodiment, the first semiconductor layer **21** can be exposed through the grooves **20*a***, the first connecting area **20*c*** and the flat area **20*b***. A bottom **20*e*** of each groove **20*a***, the first connecting area **20*c*** and the flat area **20*b*** are the exposed parts of the first semiconductor layer **21**.

The number of the grooves **20*a*** is three in the present embodiment. The three grooves **20*a*** define four finger areas **81**, **82**, **83**, **84** and a second connecting area **85** in the light emitting structure **20**. Each groove **20*a*** is located between two adjacent finger areas. In FIG. **1**, there are a first finger area **81**, a second finger area **82**, a third finger area **83**, and a fourth finger area **84** distributed from left to right. The first finger area **81**, the second finger area **82**, the third finger area **83**, and the fourth finger area **84** are perpendicular to and extend from the second connecting area **85**. The second connecting area **85** is opposite to the first connecting area **20*c***. The second connecting area **85** is parallel to the first connecting area **20*c***.

A first electrode **30** can be formed on the first semiconductor layer **21** by evaporation, sputtering, etc. The first electrode **30** can be made of gold (Au). The first electrode **30** includes a first body **31**, a first arm **33** and a plurality of first fingers **32**. The first fingers **32** are perpendicular to and extend from the first arm **33**. The first arm **33** extends from the first body **31**. The first body **31** is formed on the flat area **20***b*. The first arm **33** is formed on the first connecting area **20***c*. Each first finger **32** is formed on the bottom **20***e* of a groove **20***a* corresponding to the first finger **32**. The first fingers **32** are parallel to each other. In at least one embodiment, a cross-section of the first fingers **32** is trapezoid which has a top edge **91** and a bottom edge **92**. A width of the top edge **91** is shorter than that of the bottom edge **92**.

A second electrode **40** can be formed on the second semiconductor layer **23** by evaporation, sputtering, etc. The second electrode **40** can be made of Au. The second electrode **40** includes a second body **41**, a second arm **43** and a plurality of second fingers **42**. The second fingers **42** are perpendicular to and extend from the second arm **43**. The second arm **43** extends from the second body **41**. The second fingers **42** are parallel to each other. The second body **42** is formed on a corner area **20***d* of the light emitting structure **20**. The corner area **20***d* is opposite to the flat area **20***b*. The second arm **43** is formed on the second connecting area **85**. The second fingers **41** are formed on the four finger area **81**, **82**, **83**, **84**. In at least one embodiment, the second electrode **40** can be formed on the transparent conducting layer **24**.

The first arm **33** of the first electrode **30** can be parallel to the second arm **43** of the second electrode **40**.

A first transparent protecting layer **60** can be formed on the light emitting structure **20**. The first transparent protecting layer **60** covers the transparent conducting layer **24**, the bottoms **20***e* and the flanks **20***d* of the grooves **20***a*, the first fingers **32** and the first arm **33** of the first electrode **30** and the second fingers **42**, the second arm **43** of the second electrode **40**. The first body **31** of the first electrode **30** and the second body **41** of the second electrode **40** are exposed through the first transparent protecting layer **60**. The first transparent protecting layer **60** can be made of silicon dioxide, silicon nitride (Si_3N_4) or titanium dioxide (TiO_2).

A reflection layer **50** is formed on the first transparent protecting layer **60**. The reflection layer **50** can be made of aluminum (Al), titanium (Ti), chromium (Cr), nickel (Ni), argentums (Ag), platinum (Pt), tungsten (W), rhodium (Rh) or molybdenum (Mo). As shown in FIG. **2**, a part of the first transparent protecting layer **60** formed on the first fingers **32** is covered by the reflection layer **50**.

A second transparent protecting layer **70** is formed on the reflection layer **50**. The second transparent protecting layer **70** can be made of silicon dioxide, silicon nitride or titanium dioxide. The second transparent protecting layer **70** can cover the reflection layer **50**.

Referring to FIG. **3**, a flowchart is presented in accordance with an embodiment of a method of manufacturing an LED die. The method **300** is provided by way of example, as there are a variety of ways to carry out the method. The method **300** described below can be carried out using the configurations illustrated in FIGS. **1** and **2**, for example, and various elements of these figures are referenced in explaining the method **300**. Each block shown in FIG. **3** represents one or more process, method, or subroutines, carried out in the method **300**. Furthermore, the illustrated order of blocks is illustrative only and the order of the blocks can be changed. Additional blocks can be added or fewer blocks may be utilized without departing from this disclosure. The method **300** can begin at block **301**.

At Block **301**, a substrate **10** is provided. A light emitting structure **20** is formed on the substrate **10**. The light emitting structure **20** includes a first semiconductor layer **21**, an active layer **22** and a second semiconductor layer **23**. The first semiconductor layer **21**, the active layer **22**, the second semiconductor layer **23** are successively formed on the substrate **10**. In at least one embodiment, the light emitting structure **20** also includes a transparent conducting layer **24**. A transparent conducting layer **24** is formed on the second semiconductor layer **23**.

At Block **302**, a plurality of grooves **20***a*, a first connecting area **20***c* and a flat area **20***b* are formed on the light emitting structure **20**. A part of first semiconductor layer **21** is exposed. The grooves **20***a*, a first connecting area **20***c* and a flat area **20***b* can be made by etching the light emitting structure **20** to expose the first semiconductor layer **21**. The grooves **20***a* can be parallel to each other. In at least one embodiment, a bottom **20***e* of each groove **20***a*, the first connecting area **20***c* and the flat area **20***b* are the exposed part of the first semiconductor layer **21**. A flank **20***f* of each groove **20***a* can be an inclined surface.

In at least one embodiment, the number of the grooves **20***a* is three. The three grooves **20***a* define four finger areas **81**, **82**, **83**, **84** and a second connecting area **85** in the light emitting structure **20**. Each groove **20***a* is located between two adjacent finger areas. The four finger areas **81**, **82**, **83**, **84** are perpendicular to and extended from the second connecting area **85**. The second connecting area **85** is opposite to the first connecting area **20***c*. The second connecting area **85** is parallel to the first connecting area **20***c*.

At Block **303**, a first electrode **30** is formed on the first semiconductor layer **21**. A second electrode **40** is formed on the transparent conducting layer **24**. The first electrode **30** includes a first body **31** formed on the flat area **20***b*, a first arm **33** formed on the first connecting area **20***c* and a plurality of first fingers **32** formed on the grooves **20***a*. The second electrode **40** includes a second body **41** formed on a corner area **20***d*, a second arm **43** formed on the second connecting area **85** and a plurality of second fingers **42** formed on the finger areas **81**, **82**, **83**, **84**.

It is understood that there are no particular limitations on the number of the grooves and the number of finger areas.

At Block **304**, a first transparent protecting layer **60** is formed on the first electrode **30**. The first transparent protecting layer **60** can cover the transparent conducting layer **24**, the bottoms **20***e* and the flanks **20***d* of the grooves **20***a*, the first fingers **32** and first arm **33** of the first electrode **30** and the second fingers **42** and the second arm **43** of the second electrode **40**. The first body **31** of the first electrode **30** and the second body **41** of the second electrode **40** are exposed through the first transparent protecting layer **60**.

At Block **305**, a reflection layer **50** can be formed on the first transparent protecting layer **60**. The first transparent protecting layer **40** formed on the first fingers **32** can be covered by the reflection layer **50**.

At Block **306**, a second transparent protecting layer **70** can be formed on the reflection layer **50**. The second transparent protecting layer **70** can cover the reflection layer **50**.

It is to be further understood that even though numerous characteristics and advantages have been set forth in the foregoing description of embodiments, together with details of the structures and functions of the embodiments, the disclosure is illustrative only; and that changes may be made in detail, including in matters of shape, size, and arrangement of parts within the principles of the disclosure to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

The embodiments shown and described above are only examples. Many details are often found in the art such as the other features of an LED die and a method of manufacturing the LED die. Therefore, many such details are neither shown nor described. Even though numerous characteristics and advantages of the present technology have been set forth in the foregoing description, together with details of the structure and function of the present disclosure, the disclosure is illustrative only, and changes may be made in the detail, including in matters of shape, size and arrangement of the parts within the principles of the present disclosure up to, and including the full extent established by the broad general meaning of the terms used in the claims. It will therefore be appreciated that the embodiments described above may be modified within the scope of the claims.

What is claimed is:

1. An LED die comprising:

a substrate;

a light emitting structure comprising a first semiconductor layer, an active layer, a second semiconductor layer successively formed on the substrate, and a part of first semiconductor layer being exposed;

a first electrode formed on the exposed part of the first semiconductor layer;

a second electrode formed on the second semiconductor layer; and

a first transparent protecting layer, a reflection layer, and a second transparent protecting layer successively formed on the first electrode.

2. The LED die of claim **1**, wherein the first semiconductor layer is exposed by etching.

3. The LED die of claim **1**, further comprising a transparent conducting layer formed on the second semiconductor layer, and the second electrode is formed on the transparent conducting layer.

4. The LED die of claim **3**, further comprising a plurality of grooves, a first connecting area and a flat area connecting with each other, the grooves, the first connecting area and the flat area are formed from the transparent conducting layer to the first semiconductor layer by etching, and the part of first semiconductor layer is exposed through the grooves, the first connecting area and the flat area.

5. The LED die of claim **4**, wherein the grooves are parallel to each other.

6. The LED die of claim **4**, wherein each groove comprises a flank, and each flank is an inclined surface.

7. The LED die of claim **4**, wherein the first electrode comprises a first body, a first arm and a plurality of first fingers, the first fingers are extended from the first arm, the first arm is extended from the first body, each first finger is formed on a bottom of each groove, the first arm is formed on the first connecting area, and the first body is formed on the flat area.

8. The LED die of claim **7**, wherein the first fingers are parallel to each other.

9. The LED die of claim **7**, wherein the light emitting structure is divided into a plurality of finger areas and a second connecting area by the grooves.

10. The LED die of claim **9**, wherein the second electrode comprises a second body, a second arm and a plurality of second fingers, the second fingers are extended from the second arm, the second arm is extended from the second body, each second finger is formed on a finger area, the second arm is formed on the second connecting area, and the second body is formed on a corner area of the light emitting structure.

11. The LED die of claim **10**, wherein the corner area is opposite to the flat area.

12. The LED die of claim **10**, wherein the second fingers are parallel to each other.

13. The LED die of claim **10**, wherein the first transparent protecting layer covers the transparent conducting layer, the bottoms and the flanks of the grooves, the first finger and the first arm of the first electrode and the second fingers and the second arm of the second electrode, the first body of the first electrode and the second body of the second electrode is exposed through the transparent protecting layer.

14. A method of manufacturing an LED die comprising:

providing a substrate, a light emitting structure formed on the substrate, the light emitting structure comprising a first semiconductor layer, an active layer and a second semiconductor layer successively formed on the substrate;

etching the light emitting structure to expose a part of the first semiconductor layer;

forming a first electrode on the first semiconductor layer and a second electrode on the second semiconductor layer;

forming a first transparent protecting layer on the first electrode;

forming a reflection layer on the first transparent protecting layer; and

forming a second transparent protecting layer on the reflection layer.

15. The method of claim **14**, further comprising: a transparent conducting layer formed on the second semiconductor layer, and the second electrode is formed on the transparent conducting layer.

16. The method of claim **15**, wherein the part of the first semiconductor layer which is exposed further comprising a plurality of grooves, a first connecting area and a flat area connecting with each other.

17. The method of claim **16**, wherein the first electrode comprises a first body, a first arm and a plurality of first fingers, the first fingers are extended from the first arm, the first arm is extended from the first body, each first finger is formed on a bottom of each groove, the first arm is formed on the first connecting area, and the first body is formed on the flat area.

18. The method of claim **17**, wherein the light emitting structure is divided into a plurality of finger areas and a second connecting area by the grooves.

19. The method of claim **18**, wherein the second electrode comprises a second body, a second arm and a plurality of second fingers, the second fingers are extended from the second arm, the second arm is extended from the second body, each second finger is formed on a finger area, the second arm is formed on the second connecting area, and the second body is formed on a corner area of the light emitting structure.

20. The method of claim **19**, wherein the first transparent protecting layer covers the transparent conducting layer, the bottoms and the flanks of the grooves, the first finger and the first arm of the first electrode and the second fingers and the second arm of the second electrode, the first body of the first electrode and the second body of the second electrode are exposed through the transparent protecting layer.

* * * * *